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Research Article

Effect of baking temperature on quality and safety of school meal biscuits

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Abstract

School meal programs have an important role in improving children's nutrition. Baking school meal biscuits takes place at a high temperature, which induces physicochemical changes in the biscuits' matrix with the emergence of heat-induced contaminants such as acrylamide and *trans*-fats. The present study aimed to investigate the effect of different baking temperatures for different times on the quality and safety of school meal biscuits and their lipid fraction. Biscuits were baked at 180, 200, and 220℃ for 10, 15, and 20 min. Proximate composition, physicochemical, acrylamide, heavy metals, preservatives, minerals, vitamins, texture profile analysis, color index, nutrition facts, and sensory evaluation were determined. Significant differences ($P<0.05$) were detected in proximate composition, quality parameters, texture, color, and sensory attributes. All samples showed *trans*-fatty acid levels below the limit assigned by the Commission Regulation (EU) 2019/649. Biscuits baked at 220℃ showed acrylamide exceeding the benchmark level set by the Commission Regulation (EU) 2017/2158. Baking biscuits at 180℃ had considerable moisture with low consumer acceptance. Biscuits baked at 200℃ for 20 min were the best in both processing temperature and time with the best quality attributes, safety, and consumer acceptance.

Keywords

school meal biscuits, baking temperature and time, quality and safety, *trans*-fatty acid, acrylamide

Abbreviations

AA – Acrylamide; FA – fatty acid; ES – Egyptian Standards; EU – European Union; GC – gas chrmatography; HPLC – high-performance liquid chromatography; ICP-MS – inductively coupled plasma mass spectrometry; ICP-OES – inductively coupled plasma optical emission spectrometry; ISO – International Organization of Standardization; IV – iodine value; LC-MS/MS – liquid chromatography tandem-mass spectrometry; LOD – Limit of detection; LOQ – Limit of quantitation; MOH – Ministry of Health; MUFA – mono unsaturated fatty acid; NFSA – National Food Safety Authority; NNI – National Nutrition Institute; OSI – oxidative stability index; PUFA – poly unsaturated fatty acid; POV – peroxide value; RI – refractive index; SFA – saturated fatty acid; TPA – texture profile analysis

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Introduction

Child malnutrition remains a major public health concern. To improve children's nutrition, many countries have implemented school meal programs as an important investment in children's long-run human capital (Fang and Zhu 2022). At least 368 million children in the world are fed daily at school through school feeding programs that are run to nurture children and improve their health (FAO and WFP 2018). The 2030 Agenda for Sustainable Development and the United Nations Decade of Action on Nutrition (2016-2025) provide an unprecedented opportunity to accelerate investments in programs and policies for improved food security and nutrition (FAO 2019a). School meal programs have an important role with a stronger emphasis on the quality, adequacy, and nutritional composition of the meals provided through nutrition guidelines and standards (NGS). Food safety is critical to monitoring and achieving the aims of school meal NGS (FAO 2019b). Regular consumption of school meals influences the eating habits of students and promotes a healthy diet (Locatelli et al. 2018).

Biscuits stuffed with date paste contain considerable soluble dietary fiber from date fruit with valuable nutrients and great potential as a sugar substitute or filler and are considered an important healthy diet rich in nutrients and calories for school children. Biscuit technologies have been developed to improve their nutritional properties by using them as a vehicle for nutrients, such as vitamins and minerals. Several studies have been carried out on the potential health benefits of biscuits for humans focusing on the fight against some diseases including micronutrient deficiency and weight loss. The improvement in biscuit quality involves novel recipes and process developments that improved the nutritional, sensory, and functional properties of biscuits (Agrahar-Murugkar 2020; Goubgou et al. 2021; Zlateva et al. 2022).

Baking school meal biscuits at a high temperature is a complex process inducing many physicochemical changes in the dough matrix such as volume expansion, evaporation of water and formation of a porous structure, denaturation of proteins, starch gelatinization, crust formation, and development of a desirable taste and pleasant flavors and browning. Starch and sucrose found in the raw materials of formulations of school meal biscuits may be hydrolyzed to form reducing sugars, which together with maltose promote the non-enzymatic browning reactions (Mesías et al. 2021). Acrylamide (AA), with a reported risk of increasing toxicological effects and cancer, emerged in biscuits at temperatures above 120℃ as a heat-induced processing contaminant produced by the Maillard reaction initiated by carbohydrates and carbonyls generated from the lipid oxidation and the reaction between asparagine and reducing sugars. Therefore, it is important to investigate the AA content in processed biscuits, to comply with the allowed limits of AA (Fernandes et al. 2019).

Based on the increasing interest in providing high-quality and safe school meals to our children, the present study aimed to evaluate the quality and safety of school meal biscuits baked at different temperatures and times to reach the optimum baking temperature and time for the end product with the best characteristics and consumer acceptance. Proximate composition, physicochemical quality parameters, fatty acid composition, oxidative stability, acrylamide, heavy metals, preservatives, minerals, vitamins, texture profile analysis, color index, nutrition facts, and sensory evaluation were determined.

Materials and Methods

Materials

Raw materials. All ingredients; wheat plain flour, shortening, date paste, sugar, vanilla, sodium bicarbonate, common salt, vitamax, and milk powder were purchased from a certified company registered in the White List of the National Food Safety Authority (NFSA), Egypt.

Chemicals and reagents. All solvents and chemicals used in the study were of analytical and HPLC grade.

Methods

Manufacturing of school meal biscuits. School meal biscuits stuffed with date paste were formulated according to the Egyptian Standards (2008) for biscuit of schools under recommendations of the National Nutrition Institute (NNI), Ministry of Health (MOH), Egypt. The ingredients in the batch include wheat plain flour

(100 kg); shortening (21 kg); date paste (50 kg), sugar (27 kg); milk powder (5 kg); vanilla (70 gm); sodium bicarbonate (300 gm); common salt (250 gm); vitamax (700 gm) as a fortification for the enrichment of micronutrients in biscuits containing considerable amounts of vitamins (A, B_1, B_2, B_3, B_5, B_6, B_7, B_9, B_{12}, D_3, E) and minerals (calcium, iron, zinc, iodine, and phosphorous).

Processing and kneading of school meal biscuits. Processing of school meal biscuits with date paste consists of definite steps: weighing and mixing of ingredients, kneading, sheeting, sheet relaxation, shape-forming, baking, and cooling until the temperature of the school meal biscuits reaches less than 35℃, and then packaging. For the current study, 9 experimental treatments ($T_{Temperature/Time}$) of school meal biscuits were processed at 180, 200, and 220℃ for 10, 15, and 20 min.

All the ingredients were weighed and mixed (except for wheat plain flour, vitamax, and date paste to prepare the cream) in a mixer (Tekno Pastry Machines – QUARTESOLO – VI – ITALY) for 5 min of mixing, wheat plain flour was added and the dough was kneaded for 20 min then vitamax was added with the date paste and mixed well. The date paste and the dough were placed in a special bowl in the biscuit forming machine to compact and form a biscuit stuffed with date paste by a biscuit filling and forming machine (LASER S.R.L. Via Saturno, 36 - TAG800 - ITALY), cut by using a stainless-steel circular mold and placed on a tray. Biscuits were baked in an electric oven (LASER, S.R.L - Via Saturno, 36 - FCI - ITALY).
For all baking conditions, the oven was preheated for the time necessary to reach and maintain a constant temperature equal to 180, 200, and 220℃, and the baking was carried out for 10, 15, and 20 min. After baking, the biscuits were removed from the oven, placed on a grid, and kept cooling at room temperature until the temperature of the biscuits reached less than 35℃. For each treatment 3 batches of about 350 biscuits per batch were produced and packed using a Tecno Pack Packaging Machine (Flow Pack F.P. 020 / ITALY).

Analytical Methods

Proximate composition, physicochemical quality parameters, fatty acid composition, iodine value, and oxidative stability of school meal biscuits. School meal biscuits were evaluated for proximate composition, physicochemical quality parameters, oxidative stability (OSI), and fatty acid composition. Moisture, ash, protein, fat, fiber, and carbohydrate content (calculated by difference), refractive index (RI), and peroxide value (POV) were determined according to AOAC Official Method 965.33 (2016). Acidity was determined according to the method described in ISO 660:2020 (2020). The fatty acid composition was converted into methyl ester and determined by gas chromatography (GC) according to the method described in ISO 12966-2:2017 (2017) and the iodine value (IV) was calculated from the fatty acid composition (Kyriakidis and Katsiloulis 2000). The oxidative stability index (OSI) was determined by the Metrohm Rancimat 679 instrument according to the method described by Gutiérrez (1989).

Determination of vitamins in school meal biscuits. Vitamins A, D, and E were determined in school meal biscuits according to the method described by Blake (2007) using high-performance liquid chromatography (HPLC). Whereas, vitamin B complexes were determined according to the method described by Salvati et al. (2016) using liquid chromatography-tandem mass spectrometry (LC-MS/MS).

Determination of minerals and heavy metals in school meal biscuits. Minerals (sodium, calcium, phosphorous, iron, zinc, and iodine) and heavy metals (lead, cadmium, and arsenic) were determined in school meal biscuits according to the method described by Sepe et al. (2003). Sodium, calcium, and phosphorous were determined using inductively coupled plasma optical emission spectrometry (ICP-OES). Whereas, iron, zinc, iodine, lead, cadmium, and arsenic were determined using inductively coupled plasma mass spectrometry (ICP-MS).

Determination of preservatives in school meal biscuits. Preservatives (benzoates and sorbates) were determined in school meal biscuits according to the method described by Saad et al. (2005) using high-performance liquid chromatography (HPLC).

Determination of acrylamide in school meal biscuits. Acrylamide content was determined in school meal biscuits according to the method described by Tölgyesi and Sharma (2020) using liquid chromatography-tandem mass spectrometry (LC-MS/MS).

Texture profile analysis (TPA) of school meal biscuits. Texture profile analysis (TPA) of school meal biscuits was carried out according to the method described by Azab et al. (2022) with slight modification for three replicates samples at 25 ± 1℃ using a Texture Analyzer (Brookfield Engineering Labs. Inc. Type CT V 1.8 Build 31 - USA) with a cylindrical probe (TA44) allowed to compress the 50 mm thick biscuit sample at a speed of 2.5 mm/sec under the force of 10 kg load cell. Biscuits were compressed to 50% of their thickness in 2 cycles.

Color measurement of school meal biscuits. Color measurement of school meal biscuits was carried out according to Palou et al. (1999) with slight modification according to Zielińska and Pankiewicz (2020) using a colorimeter (Hunterlab, USA), where L* (lightness), a* (redness), b* (yellowness), and the total color variation index (ΔE), hue (H*), chroma (C*), and browning index (BI) were calculated by equations as follows:

$$\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2} \tag{1}$$

$$C* = \sqrt{a^{*2} + b^{*2}} \tag{2}$$

$$H^* = \tan^{-1}\,[b^*/a^*] \tag{3}$$

$$BI = \frac{100}{0.17}\left(\frac{a*+1.75L*}{5.645\,L*+a*-0.012\,b*} - 0.31\right) \tag{4}$$

Nutrition facts of school meal biscuits. Nutrition facts of the school meal biscuits were determined from the analytical methods such as proximate composition, fatty acid composition, minerals, and vitamins based on recommended daily value (DV) according to Food and Drug Administration of 2000 calories per day (FDA 2022).

Sensory evaluation of school meal biscuits. Sensory evaluation of school meal biscuits baked at different temperatures for different times was done through 10 panelists chosen among colleagues in the research center (middle-aged; 5 men and 5 women), where they were asked to evaluate the product using a 9-point Hedonic scale express the extent of participants' overall liking or disliking for quality attributes: taste, color, flavor, texture, appearance, and overall acceptability (Nazir et al. 2022).

Statistical analysis. Proximate composition, physicochemical quality parameters, texture profile analysis, and color were carried out in three replicates, whereas the sensory evaluation was carried out in ten replicates, and the data were presented as mean ± standard error of the mean (SEM). The least significant difference (LSD) was tested by the T-test and analysis of one-way variance (ANOVA) at $P<0.05$.

Results and Discussion

Proximate composition of school meal biscuits baked at different temperatures for different times. The proximate composition (moisture, ash, protein, fat, fiber, carbohydrate, and energy) of school meal biscuits baked at different temperatures for different times is shown in Table 1. It is noticed significant differences among some variables such as moisture, protein, and carbohydrate. There are apparent variations within moisture contents with a maximum value (9.5093%) for biscuits baked at 180℃ for 10 min and a minimum value (7.1707%) for biscuits baked at 220℃ for 20 min due to the effect of increasing temperatures and times. Moisture content in dietary supplements can have a significant impact on organoleptic attributes such as texture, appearance, shape, taste, and weight. It affects the legal and labeling regulations and the shelf life of the dietary supplement, food quality and safety measurements, and food processing procedures. Deviations from the optimal moisture content can have a severe influence on the quality parameters of the food product, which can have implications for its safety. Therefore, moisture content determination has become a vital analysis in the food industry. Excess moisture content can cause an increase in the rate of microbial growth, which can spoil a product before it reaches the shelves. Also, low moisture contents harden the food products and affect negatively the organoleptic attributes of products, especially the texture or softness. Therefore, the moisture content should be adjusted to present the safest product from the microbiological side of view besides the highest overall consumer acceptability.

The ash content represents the total inorganic matter which includes the acid-insoluble ash as a measure of sand and other silicious matter with the acid-soluble ash portion containing minerals of important role in nutrition and physiological processes. The total ash content ranged from 1.9043% to 1.9527% for biscuits baked at 180℃ for 10 min and 220℃ for 20 min, respectively. There are small variations among the ash contents in increasing order which

could be attributed to the degradation of heat-sensitive components with increasing baking temperatures and times. The protein content ranged from 9.25% to 8.72% for biscuits baked at 180℃ for 10 min and 220℃ for 20 min, respectively. Protein content decreases with increasing baking temperatures and times. During baking, the increasing heat and time cause a protein to vibrate which destroys the weak bonds holding proteins in their complex (Patel et al. 2019). It was reported that with the increase in the baking temperature from 180 - 220℃, a significant amount decrease in the total essential amino acids due to the thermal denaturation of heat liable amino acids, along with other nitrogenous compounds (Patel et al. 2019). The fat content ranged from 10.3097% to 10.2577% for biscuits baked at 180℃ for 10 min and 220℃ for 20 min, respectively, without significant effect, which could be attributed to the considerable thermal stability of fatty acids and triglyceride. The fiber content (4.40%) remained unaltered with changing baking temperatures and times. Carbohydrate content (64.6323%-67.4830%) showed an increase with the increase in the baking temperatures and times due to changes in other constituents. Considering the energy value (calories) of the school meal biscuits, from the formulation used, it is assumed that the school meal biscuits should be high in all treatments (398 - 407 calories) as recommended for the school meal, to provide children with considerable high energy needed for their daily activities. The energy per 100 g of school meal biscuits constitutes about 20% of the daily value (DV) of 2,000 calories recommended per day for general nutrition requirements. From the determinations of the moisture content which affects the processing, storage, shelf-life, quality, and safety of biscuits, we have selected three treatments with the least moisture contents (and hence lowest microbial load) as representative of the three categories of varying temperatures (180, 200, and 220℃) with the greatest time of baking (20 min) to investigate their fatty acid composition, iodine value, oxidative stability, vitamins, minerals, heavy metals, preservatives, and acrylamide.

Physicochemical quality parameters of school meal biscuits baked at different temperatures for different times. Table 2 lists the physicochemical quality parameters of school meal biscuits baked at different temperatures for different times. Variations in refractive index (RI) values (1.4578-1.4596) were attributed to the differences in fatty acid composition as affected by the baking temperatures. It was noticed the decrease in RI with increasing the baking temperature and time. The presence of peroxides and other oxidation products imparts unpleasant odors and shortens the shelf life. The peroxide value (POV) increased with increasing baking temperatures and times, but still safe. Acidity is a measure of the amount of free fatty acids (FFA) present in oil due to both hydrolyses of its triglycerides and oxidation of double bonds of the unsaturated acyl chains which produced free fatty acids with low molecular weight (Almoselhy et al. 2021). It has been frequently used as an important parameter to monitor the quality and to show the case of hydrolysis and oxidation induced in the fat-containing products (Balev et al. 2022; Kolev 2022; Malomo et al. 2022; Vlahova-Vangelova et al. 2022). Acidity value increased with increasing baking temperatures and times but was still safe according to the Egyptian Standards (2008) for biscuit of schools.

Fatty acid composition, iodine value, and oxidative stability of school meal biscuits; raw and baked at 180, 200, and 220℃ for 20 min. (Table 3 shows the fatty acid composition (%) of raw and baked biscuits at different temperatures for 20 min ΣSFA was 52.52, 52.77, 53.15, and 53.23%, whereas, ΣUSFA was 47.48, 47.18, 46.76, and 46.71% for raw and baked at 180, 200, and 220℃, respectively. The iodine value (IV) decreased with increasing baking temperatures as it is related to the unsaturated fatty acids which decreased with increasing temperatures. The oxidative stability index (OSI) for raw and baked biscuits at 180, 200, and 220℃ was 18.30 h, 17.09 h, 16.69 h, and 16.42 h, respectively. The lowest induction period (or OSI) of 16.42 h for school meal biscuits baked at 220℃ for 20 min was attributed to its lowest antioxidant content and lowest polyunsaturated fatty acid (10.24%). The oxidative stability index only indicates a total evaluation of the antioxidant potential, without knowledge of the possible participation of single components and their positive or negative interactions. Then, the oxidative stability index is not dependent on a single parameter but is rather affected by the fatty acid composition and a complex pool of antioxidants and

Table 1. Proximate composition of school meal biscuits baked at different temperatures for different times

Formula	Moisture, %	Ash, %	Protein, %	Fat, %	Fiber, %	Carbohydrates, %	Energy, calories
T180/10	9.5093±0.0020^{a}	1.9043±0.0003^{i}	9.2500±0.0000^{a}	10.3097±0.0003^{a}	4.401±0.000^{g}	64.6323±0.0015^{i}	398.0±0.5774^{d}
T180/15	9.4250±0.0012^{b}	1.9090±0.0000^{h}	9.2300±0.0000^{b}	10.3057±0.0003^{b}	4.401±0.000^{g}	64.7333±0.0009^{h}	398.0±0.5774^{d}
T180/20	9.1017±0.0009^{c}	1.9160±0.0006^{g}	9.0067±0.0033^{c}	10.2967±0.0003^{c}	4.402±0.000^{f}	65.2883±0.0009^{g}	399.0±0.5774^{d}
T200/10	8.7630±0.0012^{d}	1.9223±0.0003^{f}	8.9567±0.0033^{d}	10.2930±0.0006^{d}	4.403±0.000^{e}	65.6737±0.0012^{f}	401.0±0.5774^{c}
T200/15	8.6437±0.0003^{e}	1.9277±0.0007^{e}	8.8767±0.0033^{e}	10.2890±0.0006^{e}	4.403±0.000^{e}	65.8700±0.0006^{e}	401.0±0.5774^{c}
T200/20	7.7907±0.0003^{f}	1.9343±0.0009^{d}	8.8500±0.0000^{f}	10.2783±0.0009^{f}	4.404±0.000^{d}	66.7970±0.0006^{d}	405.0±0.5774^{b}
T220/10	7.7437±0.0003^{g}	1.9433±0.0009^{c}	8.8100±0.0058^{g}	10.2703±0.0003^{g}	4.405±0.000^{c}	66.8420±0.0012^{c}	405.0±0.5774^{b}
T220/15	7.5433±0.0003^{h}	1.9483±0.0003^{b}	8.7633±0.0067^{h}	10.2623±0.0007^{h}	4.406±0.000^{b}	67.0713±0.0009^{b}	405.0±0.5774^{b}
T220/20	7.1707±0.0003^{i}	1.9527±0.0007^{a}	8.7200±0.0058^{i}	10.2577±0.0003^{i}	4.409±0.000^{a}	67.4830±0.0006^{a}	407.0±0.5774^{a}
LSD	0.0028	0.0017	0.0119	0.0015	0.0000	0.0028	1.7154

Values are means of three replicates ±SEM with LSD for each parameter.
Values number in the same column followed by different superscripts are significantly different at P<0.05.

Table 2. Physicochemical quality parameters of school meal biscuits baked at different temperatures for different times

Formula	RI	POV, meqO_2.kg^{-1}	Acidity, %
T180/10	1.4596±0.0000^{a}	0.9400±0.0100^{i}	0.1533±0.0145^{i}
T180/15	1.4594±0.0000^{b}	1.3333±0.0088^{h}	0.2467±0.0120^{h}
T180/20	1.4591±0.0000^{c}	2.1333±0.0145^{g}	0.3533±0.0033^{g}
T200/10	1.4590±0.0000^{d}	2.3733±0.0406^{f}	0.3800±0.0058^{f}
T200/15	1.4588±0.0000^{e}	2.9200±0.0265^{e}	0.4167±0.0033^{e}
T200/20	1.4584±0.0000^{f}	3.1733±0.0088^{d}	0.4600±0.0058^{d}
T220/10	1.4582±0.0000^{g}	3.2700±0.0115^{c}	0.4833±0.0033^{c}
T220/15	1.4580±0.0000^{h}	3.4267±0.0088^{b}	0.5133±0.0067^{b}
T220/20	1.4578±0.0000^{i}	3.5933±0.0186^{a}	0.5600±0.0058^{a}
LSD	0.0000	0.0575	0.0229

POV – Peroxide value; RI – Refractive index. Values are means of three replicates ±SEM with LSD for each parameter.
Values in the same column followed by different superscripts are significantly different at P<0.05.

prooxidants (Almoselhy 2021). The high baking temperature for a long time induces the lipid oxidation processes resulting in the emergence of *trans*-fatty acids as observed in Table 3.

Table 3. Fatty acid composition of school meal biscuits; raw and baked at different temperatures for 20 min

Fatty acid, %	Raw	School meal biscuits baked for 20 min 180℃	200℃	220℃
$C_{12:0}$	0.17	0.17	0.18	0.18
$C_{14:0}$	1.03	1.02	1.02	1.02
$C_{16:0}$	46.16	46.34	46.48	46.55
$C_{16:1}$	0.18	0.18	0.18	0.18
$C_{17:0}$	0.11	0.11	0.11	0.11
$C_{17:1}$	0.02	0.02	0.02	0.02
$C_{18:0}$	4.62	4.69	4.89	4.90
$C_{18:1}$	36.76	36.48	36.14	36.11
$C_{18:2\ Trans}$	-	0.18	0.185	0.19
$C_{18:2}$	10.09	9.94	9.86	9.85
$C_{18:3}$	0.28	0.23	0.22	0.20
$C_{20:0}$	0.36	0.37	0.39	0.39
$C_{20:1}$	0.15	0.15	0.16	0.16
$C_{22:0}$	0.07	0.07	0.08	0.08
ΣSFA	52.52	52.77	53.15	53.23
ΣUSFA	47.48	47.18	46.76	46.71
ΣMUFA	37.11	36.83	36.50	36.47
ΣPUFA	10.37	10.35	10.26	10.24
IV	51.82	51.66	51.18	51.11
OSI (h)	18.30	17.09	16.69	16.42

MUFA – Mono unsaturated fatty acid; PUFA – Poly unsaturated fatty acid; SFA – Saturated fatty acid; USFA – Unsaturated fatty acid; IV – Iodine value; OSI – Oxidative stability index

All the baked samples showed *trans*-fatty acid contents below the allowed limits assigned by official regulations (Commission Regulation (EU) 2019/649). From the fatty acid composition of different samples baked at different temperatures for 20 min, it could be concluded that there is a change to be considered which agreed with the observed change in the oxidative stability which recorded 18.30, 17.09, 16.69, and 16.42 h for the raw sample and school meal biscuits samples baked at 180, 200, and 220℃, respectively.

Determination of vitamins, minerals, heavy metals, preservatives, and acrylamide in school meal biscuits baked at 180, 200, and 220℃ for 20 min. Vitamins, minerals, heavy metals, preservatives, and acrylamide contents in school meal biscuits are listed in Table 4. Differences were observed where the effect of increasing baking temperature appeared in the decreasing contents of vitamins due to the increasing volatility with loss in contents accompanying increasing temperatures. For minerals, differences were observed, where the effect of increasing baking temperature appeared in the decreasing contents of minerals due to the increasing volatility. Heavy metals were not detected and also preservatives were not detected in all samples, whereas, acrylamide (AA) emerged in all samples with varying concentrations of 123, 145, and 320 $\mu g.kg^{-1}$ for samples baked at 180, 200, and 220℃, respectively. The emergence of acrylamide is a well-known thermal processing food contaminant with serious health risks, resulting from the Maillard reaction between amino acids constituting protein of cereals and flour used in the formulation of school meal biscuits and reducing sugars. Therefore, it is important to determine the acrylamide content in processed biscuits under high temperatures and times, to comply with the allowed limits of acrylamide (Fernandes et al. 2019). Biscuits baked at 220℃ for 20 min showed AA content exceeding the benchmark level (150 $\mu g.kg^{-1}$) in biscuits and rusks for infants and young children (Commission Regulation (EU) 2017/2158).

Texture profile analysis (TPA) of school meal biscuits baked at different temperatures for different times. Texture profile analysis (TPA) is considered an important criterion to determine food quality. School meal biscuits stuffed with date paste contain 50 kg of date paste, 5 kg of milk powder, and 21 kg of shortening per 100 kg of wheat plain flour per batch. Thereby, the considerably high ratio of the date paste and shortening could soften the product and give it some elasticity. The products under study are different from just the hard biscuits

Table 4. Determination of vitamins, minerals, heavy metals, preservatives, and acrylamide in school meal biscuits baked at 180, 200, and 220℃ for 20 min

	Biscuits baked for 20 min		
Parameter	**180ºC**	**200ºC**	**220ºC**
Vitamins			
A, µg.kg^{-1}	5000	4000	3500
B_1, mg.kg^{-1}	8.0	7.2	6.5
B_2, mg.kg^{-1}	7.9	7.5	6.0
B_3, mg.kg^{-1}	45.5	41.0	37.0
B_5, mg.kg^{-1}	50.0	41.0	37.30
B_6, mg.kg^{-1}	9.0	7.8	6.9
B_7, µg.kg^{-1}	1400	1380	1300
B_9, µg.kg^{-1}	7.9	7.1	6.0
B_{12}, µg.kg^{-1}	8.2	7.2	5.8
D_3, µg.kg^{-1}	60	40	30
E, mg.kg^{-1}	85	72.5	67.3
Minerals			
Sodium, mg.kg^{-1}	501.05	500.00	499.57
Calcium, mg.kg^{-1}	1750.09	1750.00	1749.17
Phosphorous, mg.kg^{-1}	477.35	477.25	477.13
Iron, mg.kg^{-1}	86.14	86.00	85.97
Zinc, mg.kg^{-1}	57.56	57.50	57.49
Iodine, µg.kg^{-1}	603	600	599
Heavy metals			
Lead	ND	ND	ND
Cadmium	ND	ND	ND
Arsenic	ND	ND	ND
Preservatives	ND	ND	ND
Benzoates	ND	ND	ND
Sorbates	ND	ND	ND
Acrylamide, µg.kg^{-1}	123	145	320

ND – Not Detected

manufactured mainly from wheat plain flour without date paste or any soft filler ingredients. TPA was performed for school meal samples and the hardness, cohesiveness, springiness, gumminess, and chewiness were tabulated in Table 5, where significant differences ($P<0.05$) were observed among values within the same parameter indicating the effectiveness of TPA as a descriptive criterion characterizing school meal biscuits. Hardness, as a maximum force to compress a sample, ranged from 29.8633 N (for biscuits baked at 180℃ for 10 min) to 67.81 N (for biscuits baked at 220℃ for 20 min), where the hardness values increased due to moisture loss with increasing baking temperatures and times. Considering the consumer acceptance, the product of high hardness is not favorable, and also the product of low hardness is considered of lower safety as it has more moisture content, so we can consider the intermediate between the aforementioned values as preferred as it has low moisture content with acceptable hardness. The cohesiveness parameter is related to the internal structure, showing its cohesive forces maintaining the compact structure, ranging from 0.1053 to 0.1397, as low values of cohesiveness contribute positively to consumer acceptance of their higher ability for release. Springiness is related to elasticity as indicating the extent to which food can return to its original shape after the removal of compression force. It ranged from 2.8833 - 2.6033%, with the highest springiness for biscuits baked at 180ºC for 10 min and the values decreased gradually with raising the baking temperature and time to reach its minimum value of 2.6033% for biscuits baked at 220℃ for 20 min This observation could be related to the decreasing contents of moisture which increase the firmness of biscuits and resist elasticity and thereby it is well related to the increasing hardness and cohesiveness with increasing baking temperatures and times. Gumminess is considered a quality indicator for semisolid foods as the force in newton required to disintegrate a semi-solid food to a state ready for swallowing. Whereas, chewiness is dedicated to solid foods. Gumminess ranged from 7.5533 N for biscuits baked at 180ºC for 10 min to 8.5667 N for biscuits baked at 220℃ for 20 min, whereas, chewiness ranged from 1.1827 N×10^{-2} for biscuits baked at 180℃ for 10 min to 2.1267 N×10^{-2} for biscuits baked at 220℃ for 20 min with increasing values along with increasing baking temperatures and times, and could be related also to the decreasing moisture content with increasing hardness and cohesiveness. During baking, the sucrose melts and infiltrates into the dough. On cooling, it forms a glass that embeds and envelops the flour particles. This sugar glass matrix is responsible for the strength and cohesiveness of biscuits and is primarily responsible for the gross crumb structure and physical texture of hard wheat plain flour biscuits Adedara and Taylor (2021).

Table 5. Texture profile analysis (TPA) of school meal biscuits baked at different temperatures for different times

Formula	Hardness, N	Cohesiveness	Springiness, %	Gumminess, N	Chewiness, N×10^{-2}
T180/10	29.8633±0.0467^{h}	0.1053±0.0003^{i}	2.8833±0.0033^{a}	7.5533±0.0088^{h}	1.8270±0.0021^{i}
T180/15	31.3433±0.0120^{g}	0.1093±0.0003^{h}	2.8533±0.0033^{b}	7.6333±0.0088^{g}	1.8673±0.0019^{h}
T180/20	31.3633±0.0176^{g}	0.1110±0.0000^{g}	2.8067±0.0033^{c}	7.7233±0.0176^{f}	1.8983±0.0009^{g}
T200/10	46.4700±0.0321^{f}	0.1147±0.0003^{f}	2.7567±0.0088^{d}	7.8200±0.0379^{e}	1.9570±0.0021^{f}
T200/15	47.3767±0.0433^{e}	0.1190±0.0000^{e}	2.7200±0.0058^{e}	8.0500±0.0058^{d}	1.9947±0.0015^{e}
T200/20	48.3333±0.0376^{d}	0.1233±0.0009^{d}	2.6933±0.0033^{f}	8.0733±0.0033^{d}	2.0217±0.0026^{d}
T220/10	65.0867±0.0260^{c}	0.1327±0.0003^{c}	2.6367±0.0067^{g}	8.3767±0.0067^{c}	2.0770±0.0021^{c}
T220/15	66.3800±0.0346^{b}	0.1367±0.0003^{b}	2.6133±0.0033^{h}	8.4767±0.0088^{b}	2.1017±0.0015^{b}
T220/20	67.8100±0.0153^{a}	0.1397±0.0003^{a}	2.6033±0.0033^{h}	8.5667±0.0176^{a}	2.1267±0.0009^{a}
LSD	0.0943	0.0012	0.0148	0.0483	0.0053

Values are means of three replicates ±SEM with LSD for each parameter.
Values in the same column followed by different superscripts are significantly different at P<0.05.

Color measurement of school meal biscuits baked at different temperatures for different times. Color is considered a very important quality parameter as the consumers are attracted visually and show great acceptability of products. The color measurement of school meal biscuits baked at different temperatures for different times is summarized in Table 6. Significant differences (P<0.05) were observed in all color indices which reflects the apparent effect of changing temperatures and times of baking. ΔL* values ranged from 63.5 (for biscuits baked at 180℃ for 10 min) to 42.5 (for biscuits baked at 220℃ for 20 min). The decrease of the ΔL* values with increasing baking temperatures and times means that the biscuit's surface turns darker. The color of the biscuits was pale cream for treatments at 180℃, golden for treatments at 200℃, then brown golden for treatments at 220℃. Considering Δa* values, which mean redness which was influenced by thermal processing (Azab et al., 2022), where its value increased with increasing the baking temperature and time where it ranged from 10.8 for biscuits baked at 180℃ for 10 min to reach its maximum at 16.0 for biscuits baked at 220℃ for 20 min, whereas, the yellowness Δb* values decreased.

Table 6. Color measurement of school meal biscuits baked at different temperatures for different times

Formula	ΔL*	Δa*	Δb*	ΔE	C*	H*	BI
T180/10	63.5±0.053^{a}	10.8±0.003^{i}	33.6±0.005^{a}	72.7±0.024^{a}	35.3±0.011^{c}	72.2±0.019^{a}	12.1±0.000^{g}
T180/15	62.9±0.054^{b}	11.0±0.003^{h}	33.9±0.005^{a}	72.3±0.023^{b}	35.6±0.009^{b}	72.0±0.016^{b}	12.4±0.000^{g}
T180/20	62.7±0.051^{c}	11.1±0.003^{g}	34.0±0.005^{a}	72.2±0.023^{c}	35.8±0.009^{a}	71.9±0.017^{c}	12.6±0.000^{f}
T200/10	52.9±0.046^{d}	13.7±0.003^{f}	31.8±0.007^{ab}	63.2±0.024^{d}	34.6±0.008^{f}	66.7±0.014^{d}	18.1±0.000^{e}
T200/15	52.7±0.046^{e}	13.8±0.003^{e}	31.9±0.005^{b}	63.1±0.026^{e}	34.8±0.008^{e}	66.6±0.015^{e}	18.3±0.000^{e}
T200/20	52.2±0.040^{f}	13.9±0.003^{d}	32.0±0.006^{a}	62.8±0.025^{f}	34.9±0.007^{d}	66.5±0.017^{f}	18.5±0.000^{d}
T220/10	43.9±0.049^{g}	14.8±0.003^{c}	25.7±0.005^{ab}	53.0±0.023^{g}	29.7±0.007^{i}	60.1±0.016^{g}	23.1±0.000^{c}
T220/15	43.1±0.044^{h}	15.3±0.003^{b}	26.1±0.004^{ab}	52.7±0.024^{h}	30.3±0.006^{h}	59.6±0.012^{h}	24.3±0.000^{b}
T220/20	42.5±0.047^{i}	16.0±0.003^{a}	26.4±0.004^{ab}	52.5±0.023^{i}	30.9±0.006^{g}	58.8±0.013^{i}	25.6±0.000^{a}
LSD	0.1439	0.0168	0.0241	0.0114	0.0087	0.0081	0.0000

Values are means of three replicates ±SEM with LSD for each parameter.
Values in the same column followed by different superscripts are significantly different at P<0.05.

The total color difference (ΔE) ranged from 72.7 (for biscuits baked at 180℃ for 10 min) to 52.5 (for biscuits baked at 220℃ for 20 min), where it was concluded the decrease in total color difference (ΔE) with increasing temperatures and times. The chroma C* values ranged from 35.3 (for biscuits baked at 180℃ for 10 min) to 30.9 (for biscuits baked at 220℃ for 20 min), where it was concluded the decrease in saturation of the color with increasing temperatures and times. The hue H* values ranged from 72.2 (for biscuits baked at 180℃ for 10 min) to 58.8 (for biscuits baked at 220℃ for 20 min), indicating that all samples were in the red-yellow region with decreasing shift from red to the yellow region with increasing temperatures and times. Considering the Browning Index (BI), which is considered an important indicator of inhibition in the Maillard reaction which emerges by the reaction between amino groups and reducing sugars, BI values ranged from 12.1 (for biscuits baked at 180℃ for 10 min) to 25.6 (for biscuits baked at 220℃ for 20 min), with higher temperatures for higher times accelerating the browning reactions with changes in aroma, taste, and color of food products (Azab et al. 2022), where it was concluded the increase in browning index with increasing temperatures and times. Browning in biscuits results from two simultaneously occurring processes; the Maillard reaction where sugars interact with amino acids, and caramelization which is a direct degradation of sugars (Walker et al. 2012).

Nutrition facts of school meal biscuits. Nutrition facts are considered an important mandatory act for labeling food products and dietary supplements to show the real values of the essential nutrients including fat, carbohydrate, dietary fiber, protein, minerals, vitamins, and calories per serving for health purposes based on 2,000 calories per day and are used for general nutrition advice. The percentages of the daily values (%DV) were calculated per 100 gm of the serving size of school meal biscuits according to the last updated document of Daily Value on the New Nutrition and Supplement Facts Labels. The % Daily Value (DV) tells you how much a nutrient in a serving of food contributes to a daily diet (FDA 2022).

School meal biscuits stuffed with date paste are rich in protein (8.85g - 17.7% DV), carbohydrate (66.8g - 24.3% DV), dietary fiber (4.4g - 15.7% DV), fat (10.28g - 13.2% DV), minerals: calcium (175mg - 13.5% DV), phosphorous (47.73mg - 3.8% DV), iron (8.6mg - 47.7% DV), zinc (5.75mg - 52.3% DV), iodine (60mcg - 40% DV) and vitamins: A (400mcg - 44.4% DV), B_1 (0.72mg - 60% DV), B_2 (0.75mg - 57.7% DV), B_3 (4.1mg - 25.6% DV), B_5 (4.1mg - 82% DV), B_6 (0.78mg - 45.9% DV), B_7 (138mcg - 46% DV), B_9 (0.71mcg - 0.18% DV), B_{12} (0.70mcg - 29.2% DV), D_3 (4mcg - 20% DV), E (7.25mg - 78.3% DV) and high calorie (405 cal. - 20.25% DV)

Sensory evaluation of school meal biscuits baked at different temperatures at different times. Table 7 summarizes the sensory evaluation of school meal biscuits baked at different temperatures for different times. Significant differences ($P<0.05$) existed among all biscuit samples baked at different temperatures and times which reflect the apparent effect of changing temperatures and times of baking. Regarding taste, color, flavor, texture, and appearance, the scores ranged from 7.131 - 8.576, 6.799 - 8.900, 7.450 - 8.724, 6.976 - 8.281, 7.476 - 8.763 for the aforementioned attributes, respectively, with overall acceptability ranged 7.204 - 8.527. Samples baked at 200 ºC for 20 min were the best acceptable according to the sensory evaluation scores.

There was a strong relationship between the moisture content, color indices, and acrylamide content. Increasing the baking temperature and time resulted in decreasing moisture content with increasing the browning index (BI) with the emergence of acrylamide as a result of the Maillard reaction between amino acids (wheat protein) and the reducing sugar, induced by the increase in temperature.

From the aforementioned results of proximate composition, physicochemical quality parameters, acrylamide, texture profile analysis, color measurements, and sensory evaluation it could be concluded that baking school meal biscuits at 220ºC were accompanied by acrylamide level (320 μg/kg) exceeding the benchmark level (150 μg/kg) in biscuits and rusks for infants and young children (Commission Regulation (EU) 2017/2158) with increasing hardness and browning. Last, when considering baking biscuits at 200ºC for 20 min, it was observed the highest scores of sensory attributes with the highest overall acceptability of

Table 7. Sensory evaluation of school meal biscuits baked at different temperatures at different times

Formula	Taste	Color	Flavor	Texture	Appearance	Overall Acceptability
T180/10	7.131±0.041^{f}	6.799±0.017^{h}	7.638±0.025^{f}	6.976±0.005^{i}	7.476±0.007^{i}	7.204±0.018^{i}
T180/15	7.428±0.008^{e}	7.071±0.006^{g}	7.625±0.006^{f}	7.067±0.004^{h}	7.591±0.010^{h}	7.356±0.007^{h}
T180/20	7.748±0.010^{d}	7.378±0.020^{e}	7.962±0.004^{e}	7.169±0.004^{g}	7.742±0.010^{f}	7.573±0.021^{f}
T200/10	8.071±0.006^{c}	8.475±0.004^{b}	8.531±0.007^{b}	7.969±0.005^{c}	8.320±0.004^{c}	8.273±0.005^{c}
T200/15	8.278±0.008^{b}	8.481±0.005^{b}	8.724±0.007^{a}	8.150±0.013^{b}	8.436±0.007^{b}	8.434±0.018^{b}
T200/20	8.576±0.007^{a}	8.900±0.000^{a}	8.113±0.015^{d}	8.281±0.014^{a}	8.763±0.004^{a}	8.527±0.008^{a}
T220/10	7.472±0.005^{e}	7.313±0.003^{f}	7.450±0.000^{g}	7.219±0.005^{f}	7.665±0.003^{g}	7.424±0.003^{g}
T220/15	7.709±0.003^{d}	7.709±0.003^{d}	7.959±0.003^{e}	7.309±0.003^{e}	7.800±0.000^{e}	7.697±0.002^{e}
T220/20	8.077±0.014^{c}	8.033±0.008^{c}	8.371±0.003^{c}	7.596±0.021^{d}	7.885±0.018^{d}	7.992±0.013^{d}
LSD	0.0443	0.0273	0.0294	0.028	0.0239	0.0346

Values are means of ten replicates ±SEM with LSD for each parameter.
Values in the same column followed by different superscripts are significantly different at P<0.05.

product with low moisture and acrylamide within the benchmark level assigned by the Commission Regulation (EU) 2017/2158 and preferred texture profile with color measurements, confirming the highest quality and safety of biscuits with superior consumer acceptance.

Conclusions

The current study successfully achieved its objective by reaching the best baking temperature and time for school meal biscuits stuffed with date paste in the sustainable national school meal program. The physicochemical, microbiological, and sensory evaluation confirmed the best conditions for obtaining biscuits with the highest quality and safety. Biscuits baked at 180℃ had considerable moisture contents with lower consumer acceptability. Whereas, baking biscuits at 220℃ was accompanied by the emergence of acrylamide exceeding the benchmark level assigned for children's biscuits. It could be concluded that baking school meal biscuits at 200℃ for 20 min was the best in both processing temperature and time to achieve the best quality attributes, safety, and consumer acceptance.

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